

**Third-year report of a project entitled**

**Update of UF-IFAS Nitrogen Fertilization and Management  
Recommendations for Fresh Tomato Production in Florida  
in the BMP Era**

FDACS Contract 11259



Submitted by

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## Summary

In the context of the state-wide BMP program for vegetables, N management strategies should maximize yield while reducing environmental impact. On-farm trials with extensive grower involvement, was the primary method used in this project. Bridges were built between growers, UF/IFAS and FDACS. Total marketable and XL yields of tomato grown with seepage irrigation were significantly greater with the grower's rate in two trials, with UF/IFAS rate in one trial, and in the rest of the trials (11), no significant differences were found. These results indicate that across all trials, N rates greater than the UF/IFAS rate, may not systematically justified, but occasionally they may be. Power analysis showed that when the variance exceeds 10 box/A, a power of less than 0.80 was achieved. From an economical standpoint, chances of financial return to the growers are greater with a supplemental fertilizer application as it only takes a yield increase of 3 to 40 25-lb boxes/A to offset the cost of 100 lbs/A fertilizer amount above UF/IFAS recommendation. In other words, under current fertilizer prices and in the absence of a clearly defined environmental cost, current grower's rates represent "cheap insurance" for greater chances of profit. The economical analysis together with yield response to N rate suggest that the only way to keep using N rates above UF/IFAS rate (and thereby increasing chances of profitability) while reducing the risk on environmental impact, is to develop controlled-release based fertility programs. Under the current economical conditions, it seems more achievable to reduce environmental risk by reducing fertilizer vulnerability than by reducing fertilizer application rates. These results will be presented to the UF/IFAS Plant Nutrient Oversight Committee together with other recent research results on fertilization. One of the recommendations will be to replace single-number recommendation with ranges that consider planting season and irrigation method. Based on unanimous grower feedback, this type of project should be continued to continue increase nutrient management level, BMP adoption, and reduce the environmental impact of production.

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## **Update of UF-IFAS Nitrogen Fertilization and Management Recommendations for Fresh Tomato Production in Florida in the BMP Era**

This report covers the third year of a 3-year project which goal is to update N fertilization and management recommendations for tomato grown in Florida with seepage and drip irrigation. In the context of the state-wide BMP program for vegetables, N management strategies should maximize yield while reducing environmental impact. On-farm trials with extensive grower involvement, was the primary method used for achieving the following objectives:

### **Objective 1. Strengthen partnerships with selected south Florida vegetable growers in order to conduct nutrient management experiments under commercial growing conditions**

Thirteen round tomato (and one bell pepper) fertility trials (Table 1) were conducted during the 2006-2007 growing season on farms that not only represented 16,000 acres or 80% of staked tomato production in South Florida, but also the diversity of growing conditions in the area: 8 trials were done with seepage, two with true drip and three with a combination seepage/drip irrigation. The bell pepper trial was added based on the request of the cooperating grower. One trial was conducted in the fall 2006, nine in the winter (2006-07) and four in the spring 2007. Trials also included different varieties (mostly 'Florida 47' and 'Sebring'), plant densities (in-row spacing ranging from 18 to 24 inch/plant; 5 or 6 ft bed centers), soil type (spodosol or deep sand), and farm size (500 to 5,000 acres).

Grower's active participation and enthusiasm have been increasing steadily each year and were this year the highest of the last three years. Grower's participation and inputs into the project developed strong successful partnerships during the 2006-2007 growing season. "Partnership" and "involvement in nutrient management" are key concepts for the success of the non-regulatory, incentive-based BMP program for vegetables. Growers provided input in determining fertilizer rates and helped apply the treatments. Weekly visits throughout the growing season by project leaders were organized to discuss progress toward the goals and to review in-season weekly progress reports. These weekly progress reports were farm-by-farm reports of sap petiole analyses, water table depth, dry matter accumulation, and yield. Additionally, growers received a final report at the end of the season. In short, objective one of this project was to build bridges between growers, UF/IFAS and FDACS. A polling of cooperating growers at the end of 2007 indicated that they would like to continue this type of work. Hence, objective 1 was fully reached. In addition, most cooperating growers already are or soon will file a Notice of Intent (NOI) to implement BMPs.

### **Objective 2: Evaluate the effect of selected N application rates on plant growth, health, and production.**

Although drip and seepage irrigated production systems were targeted in this project, most work was conducted with seepage irrigation because it is still the most common

form of irrigation used in Florida for tomato production. The approach to testing fertilizer rates has been progressive. In the first year of this project (2004-2005, it was only possible to have side-by-side, 2-rate demonstrations. The rates used were typically the grower's rate and the UF/IFAS rate. In the second year, it was possible to replicate and randomize trials with large plots. In the second and third years, it became possible to test multiple rates (from close to 0 to 450 lbs N/A) in on-farm, randomized and replicated small-plot trials.

For the two-rate trials, treatments consisted of N fertilizer rates ranging from 200 to 330 lb/acre (Table 1), with each trial including at least the UF/IFAS rate (200 lbs N/A) and the grower's rate (typically greater than the UF/IFAS rate). In the multiple N-rate study, eight N rates ranged from 20 to 420 lb/A of N in 60 lb/A increment in a completely randomized block design with four replications (Table 2). Across trials, plots size varied from 0.1 to 25 acres. Data collection consisted of: (1) water table depth recorded bi-weekly throughout the growing season; (2) fresh-petiole sap  $\text{NO}_3\text{-N}$  and K concentrations measured bi-weekly beginning at first flower buds and continuing until third harvest, using ion-specific meters; and, yield and grade distribution. Harvested plots were 15 to 22-ft long row segments of 10 plants. They were clearly marked to prevent unscheduled harvest by commercial crews. Marketable green and color tomatoes were graded in the field according to USDA specifications of number and weight of extra-large (5x6), large (6x6), and medium (6x7) fruit (USDA, 1997) of green and colored fruits. Rainfall data were collected from the nearest FAWN station. Yield data were subjected to analysis of variance (ANOVA) and means were separated using Duncan's Multiple Range Test at the 5% level of significance using SAS PROC GLM. The type II error of each yield variable in each trial was determined using SAS PROC POWER. Type II error represents the probability of accepting the null hypothesis while it is false. In other words, type II error represents the level of risk one makes in being incorrect when the null hypothesis is accepted. Typically, a type II error of 0.20 is regarded as acceptable. Type II error and power (calculated as 1-Type II error) may be calculated after the experiment using the number of replications, the observed variance (the variance may be estimated from SAS PROC GLM output using the SQRT-MSE term), and the expected mean yield difference to be detected.

Overall, weather was dry during the season 2006-07 (Table 3). In the absence of leaching rains (and late freezes in Spring plantings), it was not necessary to drain the fields to remove excess rain or the additional irrigation water used to raise the water table for frost/freeze protection. UF/IFAS fertilizer recommendations and the BMPs allow supplemental N and K fertilizer applications when qualified leaching rains occur. A leaching rain is defined as a cumulative rain of 3 inches in 3 days or 4 inches in 7 days. For each qualified leaching rain, an additional 30 lbs/A of N and 20 lbs/A of  $\text{K}_2\text{O}$  may be added. Therefore, using fall/winter/spring 2006-07 as an example, a supplemental application of 30 lbs/acre of N fertilizer was permissible in three trials (7, 8, and 9) in Palm Beach County due to three leaching rain events. Yet, on a dry year like the 2006-2007 season, the total N potentially applied would be less than the one actually applied. Because typically the type of rainfall pattern is only known at the end of the season, this type of calculation may be done only at the end of the season. However, using historical

weather data from South Florida, it may be worth determining the frequency of qualified leaching rainfalls for different planting seasons based on different El Nino Southern Oscillation (ENSO) phases. ENSO phases may help explain the regional rainfall patterns, and may allow for fertilizer recommendations that take into account the ENSO phase.

The diversity in growing conditions also resulted in different number of picks by the growers. However, arrangements were made in all trials to be able to harvest our experimental plots 3 times. Total marketable and XL yields were significantly greater with the grower's rate in two trials, with UF/IFAS rate in one trial, and in the rest of the trials (11), no significant differences were found (Table 5; Figs. 1, 2). These results indicate that across all trials, N rates greater than the UF/IFAS rate, are not justified, but occasionally they may be. Observed yield components sqrt-MSE values were 34 (76%), 8 (18%), and 3 (7%), in the 0-5, 5-10, and 10-15 variance groups, respectively (total = 45). Under the conditions of our experiments, the most frequent type of variance was between 0 and 10. Based on power analysis (Table 5), it is likely that when the variance exceeds 10 box/A, a power of less than 0.80 is achieved.

In the multiple N-rate trial (trial 11), marketable yields reached a plateau near the 120 lbs/A N rate (Table 6; Fig. 3). No leaching rainfall occurred during this Spring trial and it was not necessary to raise the water table for frost protection purposes. The other reason why yields started to plateau at that rate appeared to be due to the use of reclaimed water in that farm. Reclaimed water was not believed to be initially a substantial source of N, but yield response to N rates and the potential contribution of other N sources (Table 7). While the use of reclaimed water is good in itself, this trial highlighted the need for growers to take into account ALL sources of N in building their fertility program. In this case, our results suggest that a rate of 120-150 lbs/A of N should be sufficient when reclaimed water is used.

Petiole sap  $\text{NO}_3\text{-N}$  and K concentrations have shown consistent patterns for all seepage irrigated trials. Petiole sap  $\text{NO}_3\text{-N}$  concentrations increase during the first month, and then slowly decline. Petiole sap K concentrations remain fairly constant throughout the season. Differences in petiole sap  $\text{NO}_3\text{-N}$  and K concentrations between plants receiving the grower's N rate and the UF/IFAS N rates were small. These differences are more marked with trials that receive excessive rainfall. Overall in 2006-2007, petiole sap  $\text{NO}_3\text{-N}$  and K concentrations were consistently above the UF/IFAS sufficiency threshold for all treatments and at all stages of plant growth (Fig.3).

Based on the data collected during this project, it not possible to conclude that using rates above the UF/IFAS N rates result in a consistent yield increase (Figs.1,2). Most yield differences between UF/IFAS rates and grower's rates were not significant. Yet, in a small fraction of the trials, grower's rates resulted in a significantly higher yield, mostly at the third pick with the 6x7 grade category. Hence, a higher rate may be justified in planting seasons when three picks are made, but is more difficult to justify when only two picks are made. Two points make the determination of optimal rate in commercial field difficult. First, field variability is such that small plots (few feet long) and large size plots (few acres) do not well represent the high-yielding and low-yielding areas of large commercial fields. Understanding the spatial distribution of yield will require some form

of yield mapping. Second, the assessment of risk between traditional field-plot technique statistics and business decisions are different. Researchers' approach is to consider statistical differences, while growers' approach is to focus on business decisions.

Currently, UF/IFAS N recommendation consists in a single number (200 lbs/A) for all seasons and all irrigation systems. Our recommendation is to divide the growing season into the Fall, Winter and Spring growing seasons, and to then re-determine optimal rates based on existing data. In addition, it may be more representative of the reality of field production to replace a single number recommendation (200 lbs N/A) by a range. In addition, our recommendation is to intensify testing of controlled-release fertilizers to minimize the environmental impact of fertilization. Nevertheless, it was observed during this project that (1) grower's fertilizer awareness was increased, (2) they have conducted additional rate comparisons "on the side", and (3) N fertilizer rates in use have typically been reduced by 10% between the 2004-2005 and 2006-2007 seasons.

### **Objective 3: Evaluate the cost effectiveness of selected nitrogen application rates**

Based on current fertilizer prices and packaging costs, it takes a yield increase ranging from 2 to 40 25-lb boxes/A for market prices ranging between \$18.5 and \$4.5/25-lb box to off-set the cost of an application of 100 lb/A of N (Fig. 4). These values are very low and it is unlikely that field work with crop as variable as tomato will be able to detect yield differences so small. Also, the power associated with detecting this type of yield difference is less than 0.80 (Table 5; first column). Hence, from an economical standpoint, chances of financial return to the growers are greater with a supplemental fertilizer application. In other words, under current fertilizer prices and in the absence of a clearly defined environmental cost, current grower's rates represent "cheap insurance" for greater chances of profit.

This analysis together with yield response to N rate suggest that the only way to keep using N rates above UF/IFAS rate (and thereby increasing chances of profitability) while reducing the risk on environmental impact, is to develop controlled-release based fertility programs. Under the current economical conditions, it seems more achievable to reduce environmental risk by reducing fertilizer vulnerability than by reducing fertilizer application rates.

### **Objective 4: Propose, if needed, a change in N recommendation to the UF/IFAS Plant Nutrient Oversight Committee (PNOC).**

In the Spring of 2006, the UF/IFAS Extension Dean appointed a vegetable fertilizer task force chaired by Dan Cantliffe. Several members of this project (E. Simonne, G. McAvoy, and S. Shukla) were members of the task force together with horticulturists, agricultural engineers, and county agents. The charges to the task force were to (1) review new data generated since the last fertilizer recommendations were developed, (2) propose science-based updates, (3) develop interim recommendations where research data are missing, (4) develop a strategic plan to fill gaps in knowledge, and (5) determine funding sources for needed research. The task force's white paper outlines how recent UF/IFAS fertilizer research results may be incorporated into science-based

recommendations for Florida's vegetable farmers (Cantliffe et al., 2006). The recommendation of the task force included a proposed definition of "nutrient management recommendations", and a recommendation to replace the current single-number N recommended rate for each crop with a range that takes into account irrigation system (seepage or drip-irrigation) and planting season. This current project is included in the task force review and the task force will present its finding to the PNOC this month.

**Objective 5: Develop an extension program that facilitates the development of optimal nutrient management practices that can be utilized as BMPs.**

The Extension component of this project was thoroughly integrated with the fieldwork as the group recognized that it is essential to maintain open communication channels with our target audience if we are to improve nutrient management levels and reduce environmental impact. Partnerships were established with the growers and on-farm training was conducted as described under Objective 1. The following Extension activities were or conducted:

1. A tour of field trials was organized during the season with UF/IFAS cooperators and an FDACS representative on March 14, 2007.
2. At the end of the season, complete farm-by-farm reports have been provided to each cooperator, and results have been discussed on a one-on-one basis.
3. A debriefing session was held with all the UF/IFAS and grower cooperators at the South West Florida Research and Education Center in Immokalee on March 30, 2007.
4. Results were presented on two Certified Crop Advisor (CCA) meeting on April 4 and 25, 2007 in Lake Alfred and Sebring "Up-date nitrogen BMPs for vegetables in SW Florida" with a total of 120 attendees.
5. Results and lessons were presented to the Southwest Florida vegetable industry on April 19, 2007 in a program entitled "Tomatoes A-Z: SW Florida BMP trials results for the 2006-2007 seasons".
6. Abstract were submitted and presentations will be made by M. Ozores-Hampton, E. Simonne and F. Roka at the Annual meetings of the Florida State Horticulture Society (June 2-5, 2007), the American Society of Horticulture Science 2007 (July 18-25, 2007), and the Florida Tomato Institute in Naples, FL (September 2007).



Table 1. Summary of BMP trials conducted in South Florida during the 2006-2007 season.

Trial number	Location	Season, Planting date	Irrigation type	N rates (lb/acre) <sup>z</sup>	Plot size <sup>y</sup> (acres/rep)
2006-07					
1	Collier	Fall, Aug 31	Seepage	200 and 260	3.4 (CRD)
2	Collier	Winter, Oct 16	Drip	200 and 300	17
3	Collier	Winter, Oct 17	Seepage	200, 250, 200+C	0.17 (CRD)
4	Collier	Winter, Oct 26	Seepage	200 and 320	0.5 (CRD)
5	Collier	Winter, Nov 15	Seepage	200 and 260	3.4 (CRD)
6	Collier	Winter, Nov 27	Drip	200 and 300	25
7 <sup>x</sup>	Palm Beach	Winter, Nov 23	Seepage	200 and 300	1.8 (CRD)
8	Palm Beach	Winter, Nov 21	Seepage	200 and 300	0.9 (CRD)
9	Palm Beach	Winter, Nov 24	Seepage	200 and 300	0.9 (CRD)
10	Collier	Spring, Feb 12	Seepage	200 and 260	3 (CRD)
11	Manatee	Spring, Feb 15	Seepage	20 to 420	90' (CRD)
12	Manatee	Spring, Feb 19	Seepage/Drip	225 and 330	2 to 12
13	Manatee	Spring, Feb 19	Seepage/Drip	225 and 330	2 to 12
14	Manatee	Spring, Feb 19	Seepage/Drip	225 and 330	2 to 12

<sup>z</sup> All rates are adjusted to a 6-ft bed spacing

<sup>y</sup> CRD = completely randomized block design

<sup>x</sup> The crop was bell pepper in this trial

Table 2. Summary of rainfall amount, number of leaching rain events and possible and applied supplemental N during 2006-07 growing season in South Florida.

Trial	Season	Number of days from planting to last harvest	Total rainfall (inches)	Number of leaching rains	Possible <sup>z</sup> and applied supplemental N (lb/acre)
1	Fall	188	4.89	0	0/0
2	Winter	136	2.97	0	0/0
3	Winter	141	1.26	0	0/0
4	Winter	112	1.26	0	0/0
5	Winter	128	0.53	0	0/0
6	Winter	135	2.25	0	0/0
7	Winter		13.37	1	30/0
8	Winter	122	13.37	1	30/0
9	Winter	120	13.37	1	30/0
10	Spring	108	1.83	0	0/0
11	Spring	117	9.38	0	0/0
12	Spring	113	8.43	0	0/0
13	Spring	113	8.43	0	0/0
14	Spring	113	8.43	0	0/0

<sup>z</sup> UF/IFAS supplemental fertilizer application is allowed after a leaching rain defined as 3 inches in 3 days or 4 inches in 7 days

Table 3. Summary of statistical significance of tomato yield response to N rates in 2-rate, replicated and randomized trials during the 2006-07 season<sup>z</sup>.

Trial No.	N Rate (lbs/A)	Marketable Yield <sup>y</sup> (25-boxes/acre)			
		XL	L	M	Total
Trial		Fall			
1	200 and 260	Ns	ns	ns	Ns
		Winter			
2	200 and 300	Ns	GROWER	GROWER	Ns
3	200, 250, 200+C <sup>x</sup>	Ns	ns	ns	Ns
4	200 and 320	Ns	ns	ns	Ns
5	200 and 260	IFAS	IFAS	ns	IFAS
6	200 and 300	GROWER	ns	ns	GROWER
7	200 and 300	Ns	ns	ns	Ns
8	200 and 300	Ns	ns	ns	Ns
9	200 and 300	Ns	ns	ns	Ns
		Spring			
10	200 and 260	Ns	Ns	ns	Ns
12	225 and 330	GROWER	IFAS	IFAS	Ns
13	225 and 330	Ns	ns	ns	GROWER
14	225 and 330	Ns	ns	ns	Ns

<sup>z</sup> Grower, IFAS and ns represent yield significantly greater with grower rate, yield significantly greater with IFAS rate, and not significant at the 5% level, respectively.

<sup>y</sup> XL, L, and M represent extra-large (5x6), large (6x6) and medium (6x7) grade categories, respectively.

<sup>x</sup> A treatment with compost (C) was included in this trial

Table 4. Summary of tomato and bell pepper marketable yield response to N rates for the 2006-07 growing season.

Trial Number	Season	N rate	X- Large (5/6)	Large (6/6)	Medium (6/7)	Culls	Total yield
			------(25-lb Boxes/acre)-----				
1	Fall	200	1,476	887	628	312	2,988
	Fall	260	1,626	861	596	351	3,083
2	Winter	200	1,149	428	258	163	1,835
	Winter	300	1,035	581	398	150	2,014
	Winter	200	1,308	880	670	77	2,858
	Winter	250	1,617	826	507	58	2,949
4	Winter	200	1,504	520	443	245	2,467
	Winter	320	1,474	693	497	248	2,664
5	Winter	200	2,039	809	758	100	3,607
	Winter	260	1,855	646	596	73	3,095
6	Winter	200	1,006	552	447	142	2,006
	Winter	300	1,569	658	418	258	2,615
8	Winter	200	1,132	536	528	112	2,196
	Winter	300	1,104	472	546	172	2,123
9	Winter	200	1,351	723	504	62	2,578
	Winter	300	1,206	591	584	97	2,381
10	Spring	200	1,704	515	259	283	2,478
	Spring	260	1,678	469	375	275	2,522
12	Spring	200	2,739	835	626	359	4,199
	Spring	300	3,648	553	296	363	4,497
13	Spring	200	2,518	619	430	277	3,567
	Spring	300	3,274	839	459	472	4,573
14	Spring	200	2,985	632	437	814	4,054
	Spring	300	2,408	398	377	309	3,183
			XL	L	M	S	Total
------(28 lb-bu/acre)-----							
7 Pepper	Winter	200	292	333	263	562	1,451
	Winter	300	243	315	330	640	1,527

Table 5. Power values (1-beta) for trials with 4 replications (n=4), alpha = 0.05 and different variances and expected yield differences<sup>z</sup>

Observed variance	Expected yield difference (25-lb box/A)					
	10	20	30	40	50	75
5	0.66	0.99	0.99	0.99	0.99	0.99
10	0.22	0.66	0.94	0.99	0.99	0.99
15	0.13	0.36	0.66	0.88	0.98	0.99
20	0.09	0.22	0.43	0.66	0.84	0.99
50	0.06	0.08	0.11	0.16	0.22	0.43
100	0.06	0.06	0.07	0.08	0.09	0.15
200	0.05	0.05	0.05	0.06	0.06	0.07

<sup>z</sup> power values highlighted in blue are >0.80

Table 6. Soil-applied N treatments (cold mix + hot mix) used in a multiple-N-rate fertilizer trial with seepage-irrigated tomato grown in the Spring 2007 (Trial 11).

Treatments	Fertilizer Bottom mix <sup>z</sup> (lb N/acre)	Fertilizer Hot mix <sup>y</sup> (lb N/acre)	Fertilizer Total N Rate (lb N/acre)
1	20	0	20
2	20	40	60
3	20	100	120
4	20	160	180
5	20	220	240
6	20	280	300
7	20	340	360
8	20	400	420

<sup>z</sup> Applied by the cooperating grower using routine fertilizer during the bedding operation

<sup>y</sup> Applied by hand by UF/IFAS cooperators using ammonium nitrate. Potassium chloride was also applied by hand to keep K rate constant. After hot mix application, the fumigant was applied immediately followed by the plastic mulch.

Table 7. Non-fertilizer sources of N identified in trial 11 with tomato grown with seepage irrigation and reclaimed water during the spring season 2007.

Nitrogen Source	N Rate
	(lb/acre)
Reclaimed water effluent (NO <sub>3</sub> -N)	60
Reclaimed water effluent (NH <sub>4</sub> -N)	1.3
Reclaimed water effluent TKN	5.4
Sub-total N from reclaimed water <sup>z</sup>	67
50 % available for plants <sup>y</sup>	34
Estimated N release from organic matter (2.8 % OM) <sup>x</sup>	22
Total N supplied by non-fertilizer sources	56

<sup>z</sup> Contributions in N by the reclaimed water were calculated using daily reports from the water treatment plant

<sup>y</sup> assuming that 50% of the N supplied by the reclaimed water was used by the plants

<sup>x</sup> organic matter content in the field determined before the trial began

Fig. 1. Summary of tomato first harvest and seasonal marketable yield response to N rates in 2006-2007 in South Florida.

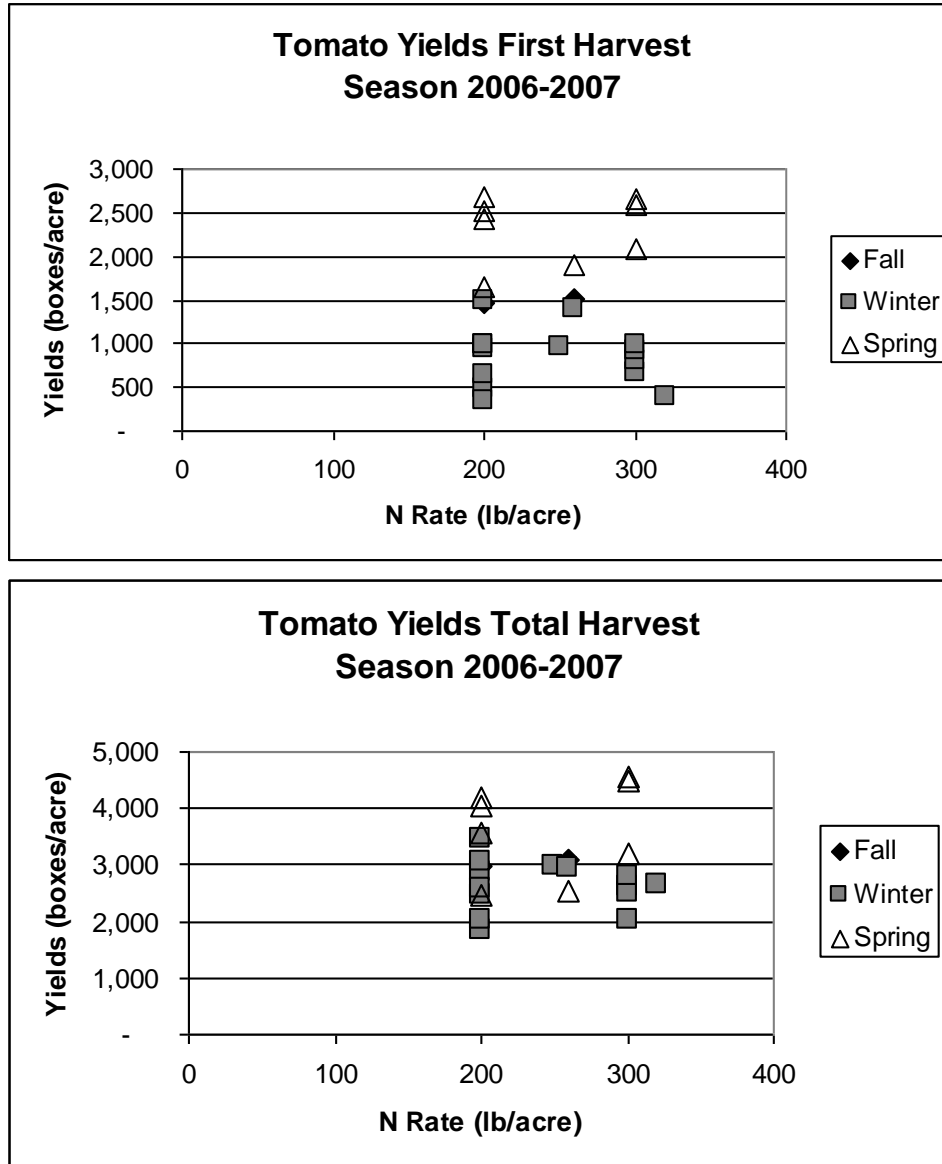




Fig 2. Effect of soil-applied N rates on tomato marketable yield during spring 2007 in Palmetto, FL (trial 11). (All rates received and estimated additional 56lbs/A of N from the reclaimed water and organic matter mineralization; table 4)

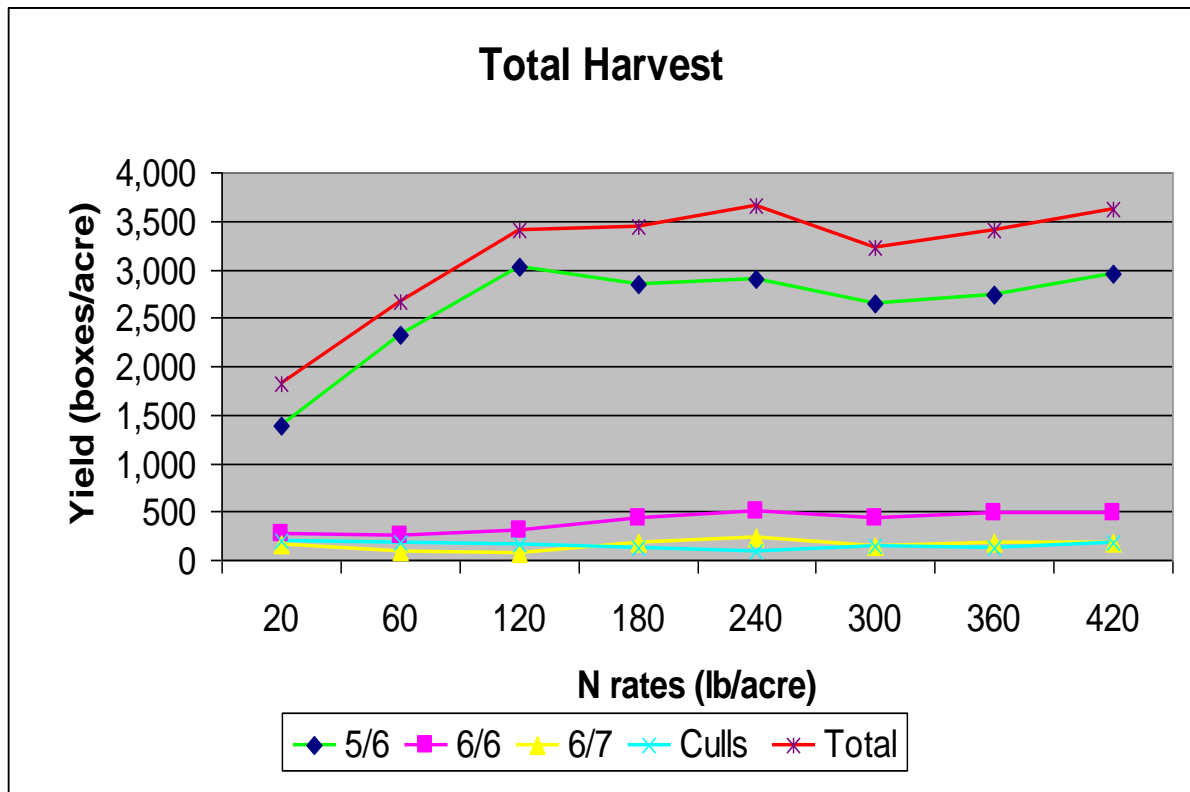


Fig. 3. Typical  $\text{NO}_3\text{-N}$  and K sap petiole concentration response throughout the season for seepage irrigated tomato.

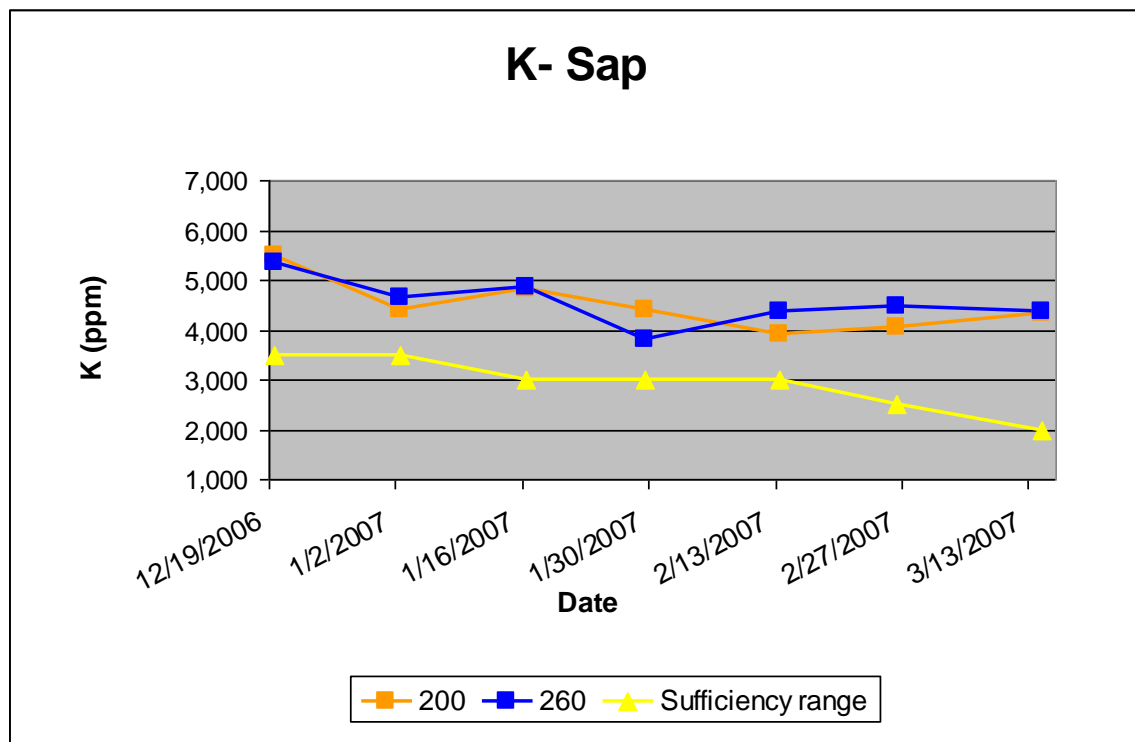
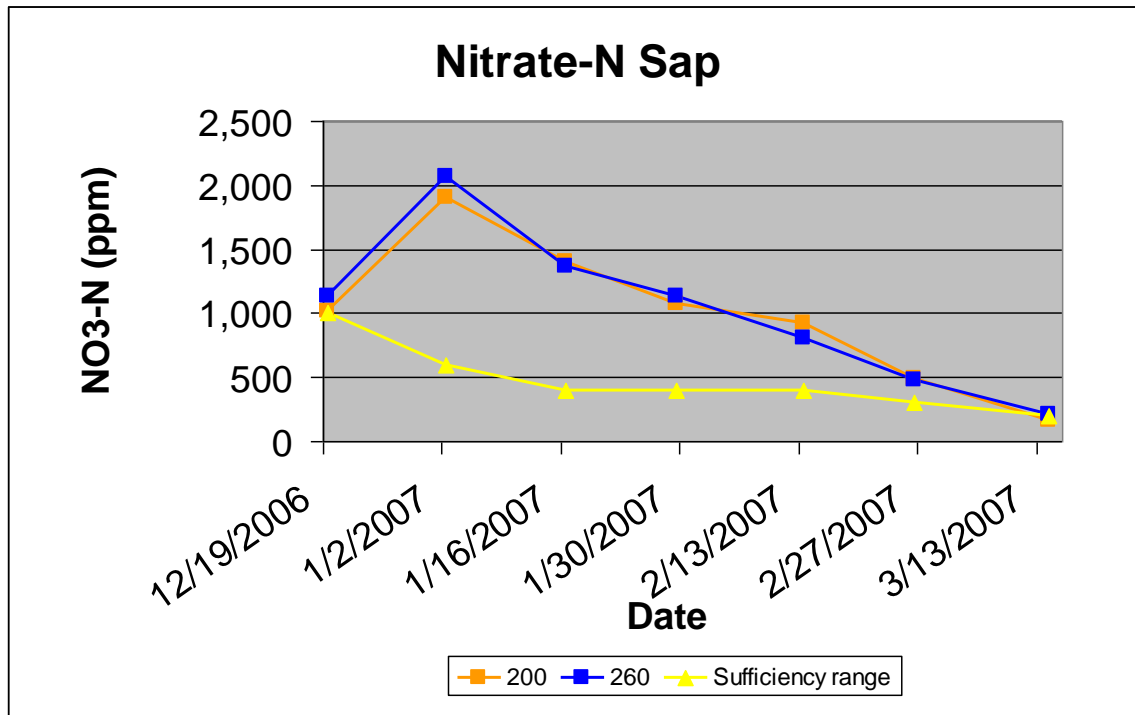


Fig. 4. Number of 25-lb boxes of tomato needed to off-set the cost of a 100 lb/A N rate above the UF/IFAS rate for market prices ranging from \$4.50 to \$18.50/25-lb box, and assuming a cost of \$0.40/lb of N and taking into account packaging cost.

